Effects of electrical and optogenetic deep brain stimulation on synchronized oscillatory activity in Parkinsonian basal ganglia

Shivakeshavan Ratnadurai-Giridharan[1], Chung C. Cheung[1], Leonid L. Rubchinsky[1,2]

[1] Department of Mathematical Sciences, Indiana University-Purdue University Indianapolis, Indianapolis, IN, USA

[2] Stark Neurosciences Research Institute, Indiana University School of Medicine, Indianapolis, IN, USA

Abstract

Objective. Deep brain stimulation (DBS) of basal ganglia targets with high-frequency regular electrical pulses is used to treat Parkinsonian motor symptoms. In spite of positive treatment effects, it has a series of limitations. In contrast, optogenetic stimulation, a new but fast growing area, is not yet at a point of clinical testing. Nevertheless, it emerges as an alternative experimental stimulation technique to affect pathological network dynamics, which may be responsible for motor symptoms. This paper compares the effects of electrical and optogenetic stimulation of the basal ganglia on the pathological parkinsonian rhythmic neural activity.

Approach. We utilized a conductance-based model of the subthalamo-pallidal circuitry, which reproduces experimentally-observed patterns of neural activity in Parkinson's disease, and consider the network response to electrical stimulation, excitatory optogenetic stimulation, and inhibitory optogenetic stimulation.

Main Results. We found that different simulation types exhibit different interactions with pathological rhythmic activity in the network. We study these interactions for different network and stimulation parameter values. We show that, in the considered model, optogenetic stimulation may be more efficient in suppressing beta oscillations than electrical stimulation.

Significance. These results indicate that optogenetic control may be more efficacious than electrical control of a network's dynamics because of the different ways of how stimulations interact with network dynamics.